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OPTIMIZATION OF PROTECTION AS A DECISION-MAKING TOOL FOR RADIOACTIVE WASTE DISPOSAL

by

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ABSTRACT

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This paper discusses whether optimization of radiation protection is a workable or helpful concept or tool with respect to decisions in the field of long-term radioactive waste management. Examples of three waste types (high-level, low-level and uranium mine tailings) are used to illustrate that actual decisions are made taking account of more complex factors and that optimization of protection plays a relatively minor role. It is thus concluded that it is not a useful general tool for waste management decision-making. Discussion of the nature of the differences between technical and non-technical factors is also presented along with suggestions to help facilitate future decision-making.

RÉSUMÉ

Le présent rapport traite de l'optimisation de la radioprotection et se demande s'il s'agit là d'un concept ou d'un outil utile ou réalisable pour prendre des décisions en gestion à long terme des déchets radioactifs. Trois exemples de déchets (haute activité, faible activité et résidus miniers d'uranium) sont présentés pour montrer que les décisions réelles prennent en considération des facteurs plus complexes et que l'optimisation de la radioprotection joue un rôle relativement mineur. On conclut donc qu'elle ne représente pas un outil général utile pour prendre des décisions relatives à la gestion des déchets. Le rapport aborde aussi la question des différences qui existent entre les facteurs techniques et non techniques, et présente certaines suggestions pour faciliter la prise de décisions futures.

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OPTIMIZATION OF PROTECTION AS A DECISION-MAKING TOOL FOR RADIOACTIVE WASTE DISPOSAL

1. Introduction

In order to discuss optimization of radiation protection as it applies to radioactive waste management, it is first necessary to make a clear distinction between the limited application of the optimization principle as it applies to radiation protection and its more general application to complete disposal systems or concepts. This paper will focus on the relationship between these two types of optimization and it will become apparent that there are fundamental differences between them. In fact there appears to be a conflict between actual decisions which are made about waste disposal systems and those which might appear to be justified based on radiation protection principles alone.

The principle question that this paper seeks to answer is, "Is optimization of radiation protection a workable or helpful concept or tool with respect to actual decisions which are necessary in the field of long-term radioactive waste disposal?" It is not intended to present a definitive summary of all applications of the optimization principle to waste disposal throughout the various NEA countries. Examples, however, will be given which characterize some of the advantages and disadvantages of the optimization principle as applied to waste disposal decisions. A further emphasis on regulatory aspects will be evident throughout the paper as in most countries it is the regulators who are the front-line agencies responsible for most of the real decisions which are made. It will become evident, however, that the regulatory agencies are not always able to make these decisions within a narrow technical perspective but will inevitably become involved in the underlying social/political framework.

The paper also excludes discussion of optimization as a tool for making decisions about the operating phases of waste facilities although it has a useful role to play in balancing costs against dose reductions. Suffice it to say that this apparently technical tool is underlain by a profoundly social value judgement implied by assigning a dollar-value to person-sievert dose reductions.

2. Examples of Waste Management Decisions

In order to provide some perspective it is useful to look at the general characteristics of three types of radioactive waste and some related decisions. The wastes chosen are uranium mine tailings, low-level waste, and high-level waste or spent nuclear fuel. In order to understand the real environment in which these wastes are addressed by decision-makers, a brief summary of their characteristics and their potential for producing doses or risks for the general population are given in Tables 1 and 2. Uranium mine tailings, for example, are unique because they contain naturally-occurring nuclides such as uranium, thorium and radium. Furthermore the concentrations of these elements are only slightly elevated with respect to natural background levels and the volume of such materials is very large (the current quantity of tailings in Canada is approximately 150 million tons). The normal approach to managing these wastes has been to dispose of them on the

land surface in close proximity to the mine-mill complex. The fact that the wastes will remain on or near the surface for very long periods of time and that the half-lives of the dominant radionuclides are extremely long gives rise to the distinct possibility that exposures to the general public both in the near term and in the very long term can occur. Such exposures generally will be dominated by intrusion pathways and in particular the problem of the tailings placed around the foundations of homes which result in elevated indoor radon levels. The magnitude of these doses can be considerable for lifetime exposure. Furthermore, real experience of known intrusions or misuse of tailings does not give confidence that institutional control, by itself, will completely prevent such exposures in the future. Therefore in the long term it is not unreasonable to hypothesize as part of the scenario analysis surrounding the safety assessment of such disposal facilities that individuals will receive exposures at levels which are clearly unacceptable by today's standards. The perception of this particular type of risk is complicated by the fact that similarly high exposures are known to occur in areas where the naturally existing level of uranium is high and yet individuals may choose to ignore the risk rather than disrupt their lives.

At the other extreme of wastes, considered in terms of their specific activity, is high-level wastes or spent nuclear fuel. It is clear that the specific activity of high-level fuel is such that as little as a few minutes direct exposure to unshielded fuel would result in a lethal dose. On the other hand, fuel which is placed in a deep geological repository is not expected to result in any dose in the near future. In the long term, that is over periods ranging from several thousands of years to several millions of years, extremely low levels of dose have been predicted in some safety assessments. Thus while the intrinsic or the inherent risk of high-level spent nuclear fuel is extremely high, the possibility of people living in the next several centuries receiving any dose whatsoever is virtually zero. The third type of waste which is low-level waste clearly falls somewhere between the others, both in terms of its intrinsic hazard, that is in terms of its specific activity and in terms of its potential for exposing members of the general public. It is possible through limitations on the type of waste going into a low-level waste disposal facility and through the appropriate application of engineering and natural barriers, to limit the level of dose received by members of the public to virtually any level which is desired.

To place this discussion of risk or detriment into the context of the optimization of radiation protection, it is also necessary to consider other factors such as the cost of the disposal facility or the amount of research money being devoted to the various types of waste. In the case of uranium mill tailings within the United States the following general trend is evident. The remedial action program in the United States has a level of funding of approximately 350 million dollars U.S. and is aimed at removing potential hazards from old tailings facilities which are not considered to be acceptable by today's standards. While this may seem a very large amount of money, it is interesting to note that the estimates for the high-level waste program are very much higher. For example, approximately one billion dollars U.S. is being estimated as the cost of evaluating a potential disposal site for the high-level wastes. Furthermore the overall costs of the complete high-level waste program in the United States probably is in the order of twenty to thirty billion dollars U.S. Therefore, the ratio of the amount of money being expended in the area of uranium mill tailings and in the high-level waste is

approximately one or two orders of magnitude. However in the context of potential for radiation exposures the opposite trend is seen; that is, the real exposures, the real risks which have occurred in the past and may well occur in the future, are greatest for uranium mill tailings and virtually zero for high-level waste. It therefore appears that the real allocation of money is in contradiction to that which would arise from studies seeking to optimize radiation protection. The implication is that the balance between the way funds are currently allocated to high level waste and to tailings needs to be adjusted so that both the potential exposures and the associated costs are more consistently addressed. It should also be noted that for the case of uranium mill tailings the potential for large collective doses is considerably greater than for high-level wastes. The production of radon which can expose very large numbers of people, albeit at very low doses, is considerable whereas for high-level waste well contained within a geological repository the potential for release of long-lived isotopes such as carbon-14 and iodine-129 is extremely low in the first several thousand years.

It must be clearly understood that this U.S. example is not in anyway unique and the situation in Canada is very similar. There have been two national waste research programs established in the last decade. The first has been completed and was directed at solving some of the problems relating to uranium mill tailings. This program had a funding level over a five year period of approximately 9 million dollars. On the other hand, the concept assessment process in Canada which is aimed at proving the viability of deep geological disposal of spent nuclear fuel is a ten or twelve-year research program funded at a level of 300 to 350 million dollars. It is therefore again evident that in dollar terms, similar amounts of money are not being spent for the two types of wastes and again, the potential risks from the two types of wastes appear to be strongly inverted in relationship to the dollar amount being spent.

The situation for low-level wastes clearly falls somewhere in between the two other types of wastes. The level of dose which is received by members of the public can vary over wide limits based on the level of engineering measures used to contain the waste. Therefore both the dose and the amount of money being expended to control the dose are variable over considerable ranges. It is not immediately clear whether the wide scope of dose and containment possibilities are consistent with the principles of optimization of protection.

The initial conclusion that could be drawn from these examples is that what is currently being done in the management of wastes is entirely inconsistent with optimization of radiation protection. However further reflection indicates that since the decisions are real and therefore are supported by the overall societies which are making them, some form of "optimization" has been done. It is this difference between what appears to be taking place in the real world and what might be seen as the logical decision arising out of a pure application of optimization principles that merits further analysis.

Several other examples can be cited which illustrate that the pure notion of optimization of radiation protection proves not to be a particularly useful overall tool. One such example occurred in the United Kingdom where a recent report entitled "Assessment of Best Practicable Environmental Options for Management of Low- and Intermediate-Level Solid Radioactive Wastes"[1]

was issued. In this study the Department of the Environment applied the process of optimization of radiation protection using multi-attribute analysis with many factors including the more traditional ones of cost and benefit. The result of this multi-attribute optimization showed a clear preference for near-surface disposal options for low-level wastes. It was, however, unable to discriminate between the various detailed options within the near-surface spectrum of disposal facilities due to the generic nature of the study. Following this report however, a government decision was made which rejected any near-surface disposal of low-level wastes and recommended that they be dealt with in a deep facility aimed at both low- and intermediate-level wastes. Thus the reality of the decision which the government made did not bear a direct relationship to a very good and a very comprehensive study based on the optimization principle. The final decision clearly incorporated broader factors which were relevant to the government of the day and therefore political, social and economic factors outside of those covered in the report must have been brought to bear. The justification of the decision however was expressed using some of the technical attributes from the study.

A related group of examples arise in those countries who have already opted for deep disposal of low-level wastes (Sweden and FRG). It is difficult to justify deep disposal on purely technical grounds as shown in the recent NEA study on shallow land burial. This report demonstrated that near surface disposal can comply with any reasonable dose criterion. Thus the decision to choose deeper burial must imply other decison-making elements since it is usually a more expensive option. From a public perception viewpoint deep burial is clearly more secure and intrusion pathways are virtually eliminated. There thus seems to be a sense that over-design is actually the most expeditious approach or the path of least resistance. This seems particularly apparent if large volumes of concrete are employed since the public regards this material as somehow more appealing than other barrier materials even though it may be technically inferior.

A final example of this apparent contradiction is the case of sea dumping. It is clear that recent technical studies conducted under the auspices of the IAEA and the NEA have shown that the direct impact in terms of dose, either individual or collective, for dumping moderate amounts of radioactive wastes at sea in the existing dump sites is extremely small. It is therefore a viable option if only technical factors are taken into consideration. However the fact that there has been a moratorium placed on any future dumping of radioactive wastes at sea is a clear indication that many countries consider that there are factors other than purely technical ones which should dominate decisions on this waste disposal option.

3. Regulatory Perspectives

In most countries the regulatory authority is caught in the middle of the decision-making process. Generally, regulators are technically oriented and therefore relate to logical and quantitative arguments presented by facility operators. On the other hand, they are the implementing arm of the broader social-political process of government. To complicate matters further, they usually are under legal obligations to make decisions - that is to issue or refuse to issue permits or licences. They do not have the luxury of procrastination and gradually develop a trench warfare mentality with its mix of concern for safety, pragmatism and focus on immediate short-term problems.

Thus theoretical approaches which focus on long-term protection, conceptual versus real effects and artificial or complex assessment methods have little intrinsic appeal. Furthermore legal precedents may arise independently of any logical or conceptual framework which severely limit a regulator's freedom of action. An example of this occurred recently in the U.S. where a court ruled that the NRC should not take account of the cost of actions needed to increase safety performance during its licensing process. Such a ruling makes a concept such as ALARA virtually unworkable.

Considerations such as these cause the regulator to both simplify and rationalize his criteria and decision-making process in order to minimize any opposition to the final decision. Increasingly, regulators have recognized the difficulties in applying the principle of optimization of radiation protection and have sought to give it a less prominent role. Table 3 is a brief summary of some countries who have taken a position on this issue and the related one of the time intervals over which long-term assessments need to be made. Table 4 attempts to illustrate why long time frames tend to be ignored in real decison making such as the deep lake tailings example presented later. It is clear that politicians are of necessity forced to act in a short-sighted manner and most individuals have little concern beyond the lifetime of their grandchildren. When this social time preference is combined with the difficulty in validating long-term predictions, and the impossibility in predicting future human and biological evolution, it is not surprising that regulators feel driven to limit the time span for predictions to periods of approximately 10^4 years. Even this "limited" period seems a bit absurd given that it is equivalent to the whole of mankind's recorded history. Regulators also need reliable tools or aids to help structure information or perceptions and to help make complex decisions. Multi-attribute analyses is one specific example which has been given recent prominence in the context of optimization of protection. While it can be helpful due to its transparency, it is imprecise since the choice of the attributes used and the weighting given to them is not unique and may be quite subjective. Thus the overall ranking which is produced by the technique is rather soft and should be used with some caution. There is, however, a duality and the soft quality of multi-attribute analysis may have considerable appeal to regulators. The ease with which overall rankings can be changed by changing the factors which are used and their weighting, normally seen as a limitation if the technique is to be used to guide decision-making, can be a real asset if the purpose is to rationalize a decision which originates on higher levels. The regulator may find himself caught trying to accommodate disparate points of view and being asked to provide a technical basis or justification for what are essentially non-technical decisions.

4. Discussion

In the earlier part of this paper several examples have been cited which suggest a contradiction between proposed decisions based upon the principles of optimization of radiation protection and those which occurred in real situations. The remainder of the paper will seek to explore some of the factors which underlie these contradictions with a focus on the long-term aspects of waste management and the differing perceptions of the technical and non-technical communities. It is important to repeat that optimization of radiation protection is as potentially applicable to the operational phase of waste management as it is to the operational phase of other parts of the

nuclear fuel cycle. However it should also be noted that the potential for large consequences is considerably different for each type of nuclear facility. The worst case dose in the waste management context will arise from intrusion scenarios for uranium mill tailings. The dose from tailings in extreme cases may represent a significant probability that lung cancer will occur but will not likely expose large numbers of people in a way similar to that which occurred during the Chernobyl disaster. One implication of this difference in worst-case dose is that the average dose in a waste environment is normally well within the stochastic dose range and therefore it is reasonable and plausible to talk about an expectation risk value which is the product of the probability of the scenario multiplied by the consequence. This is not the case for a major reactor accident where the consequence may be so large that it is clearly not appropriate from the point of view of public perception to talk about an average annual dose exposure or risk.

Another important difference in the case of wastes is that there is no direct benefit although there is clearly an indirect benefit from the power derived. Traditionally regulators have chosen to look at the overall nuclear fuel cycle and to justify it on the basis of the benefits of the electricity generated. Wastes are not therefore singled out as needing specific justification although the public may wish to maintain a separate focus. In the case of uranium tailings, the benefit may also take the form of the jobs and the general economic contribution which arise from mining operations. However, the lack of direct benefit from waste makes it difficult to offset benefit against cost or detriment. The only benefit, therefore, in such a context would be the reduction in the dose as opposed to some more tangible benefit such as an increase in the standard of living which is more easily grasped by the general public. Another problem is that some of the radioisotopes involved have extremely long half-lives. The implication of this is that active control of a waste facility by the original operator is not possible and licensing can not continue indefinitely. This lack of a traditional operator or licence means that if something goes wrong in the future, there is a need to provide for institutional mechanisms to initiate remedial action and to accept responsibility for the long-term consequences. There is therefore, the implicit assumption that the state or the local authorities will assume this responsibility and will act to prevent any serious consequences from taking place.

A lack of long-term active controls gives rise to certain perceptions and apprehensions on the part of the general public. This is manifest as a difficulty in obtaining approval for both the general concept of long-term radioactive waste disposal and, in particular, the acceptance of sites for such facilities. It is difficult to identify clearly the precise nature of the anxiety but certain general trends appear to be occurring at the present time. There appears to be a general distrust of all technical organizations whether they are the power reactor or waste facility operators or the regulators who normally employ a technical approach. To put this into its simplest form it would appear that the general public are not particularly interested in what the technical facts are and do not trust what the technical experts are telling them. This perception is compounded when the public sees experts engaged in heated technical debates involving relatively incomprehensible physical and chemical processes. Furthermore the public display a natural tendency to resist the imposition of a site on a community when they have not been consulted until after a decision has been made on

technical-optimization grounds. They see this as a loss of control arising from a perceived arrogance on the part of technocrats who choose to give more weight to technically-based aspects of decision-making rather than human and social elements. The immediate result of this is an increasing preference to store wastes in a visible form for long periods until greater confidence in long-term (i.e. invisible) disposal can be demonstrated. Such an attitude perhaps could be cited as one of the factors which underlay the decision in the U.K. to defer for approximately fifty years a definitive disposal facility for the high-level waste.

Other examples of the way the public would choose to factor elements into the decision-making process can be cited with respect to time preferences. An example of this occurred several years ago in Canada where a proposal was put forward to place uranium tailings deep underwater in a large northern lake. The technical analysis of this showed fairly clearly that there were long-term benefits from the use of such a system. However, there was a slight short-term disadvantage in that the water in the lakes and the rivers leading from that facility would have slightly elevated levels of radium and other radionuclides for a period of perhaps twenty-five or thirty years. Although the amount of radioactivity present would have been well below the appropriate drinking water standards and other regulatory criteria, it was deemed by the local authority to be an unacceptable situation and, by inference, a decision was made to accept a short-term benefit as opposed to a long-term benefit. This is a particularly clear example of where a real decision was made on the basis of a social time preference. Such decisions clearly have important implications for the ICRP optimization system which gives equal weight to exposures regardless of their time of occurrence.

The final aspect of public perception that perhaps should be considered at this stage is its relative volatility. It is fairly clear for anyone who cares to look back at the last ten or fifteen years that the issues which dominate public opinion and perception have changed on a fairly frequent basis. This is particularly awkward when the lead time for large complex systems may be as much as a generation. It is therefore virtually impossible to design a system and gain acceptance for it over a period of twenty or thirty years since the basis against which it is being judged will likely change several times over that same period.

In order to understand the apparent conflict which exists between technical and non-technical groups it is helpful to turn to the field of psychology and in particular that part dealing with personality profiles. The Myers-Briggs method[2] of characterizing personal preferences and the basis for judging events makes a distinction between those individuals who are dominant "thinkers" and those who are "feelers". This relates to the way they judge situations or make decisions and assimilate or analyze information. The "thinkers" tend to be logical, linear, impersonal and seek to validate judgements on the basis of truth while the "feelers" tend to be personal, wholistic, associative and judge via more loosely structured humanistic processes aimed at determining whether the decision is good. Most scientists and technical professionals tend to be thinkers (68%) while the population as a whole is equally divided. Women, however, are 65% feelers[3] which links to studies which have shown that typically more women than men are opposed to nuclear energy[4]. Thus techniques which appeal within technical circles are neither appealing nor easily understood by the general

population. Therefore, it is not just a matter of educating the public or simplifying our jargon. We, as technical professionals, must ultimately become aware of these underlying differences in approach and value systems and accept them as real and important, without judgement as to which might be "best" or "correct". Without such an awareness we will continue to be frustrated by the skew between our technical recommendations and real world decisions. We will also continue to delude ourselves that if we could just add one more piece of information or add one more term to our equations, or help the public to understand the beauty of our arguments, all would suddenly become resolved and harmony would be restored.

5. Future Developments

The previous sections have attempted to demonstrate that a contradiction exists between the theory of optimization of radiation protection and its relevance to real decision-making. It is therefore necessary to ask if it is possible to adjust or fine tune the theory to account for the observed discrepancies. Such an adjustment is clearly only appropriate if the underlying problem is of a technical nature. The examples and discussion given earlier suggest that the problem is more complex and that a technical fix would not work very well since it would ignore a fundamentally different way of thinking used by a large segment of the population.

It is therefore necessary to reconsider the role of technical information in the decision-making process. Clearly this type of information continues to be needed as an input to decision making and equally clearly, it will be difficult to communicate. However certain approaches can help ease the difficulties. For example, it is important to convey a sense that the technical community recognizes the limitations of its contribution and that technical "facts" are in no way special and therefore do not merit any favoured status. We often fail to convey this and thus are seen as arrogant and unwilling to listen to what we might regard as soft information. In specific terms it is important to admit that we do not have a definitive understanding of how waste disposal facilities will perform in the longer term, nor do we have any reasonable expectation that we ever will. It is also necessary to admit candidly the existence of large uncertainties in some cases. In order to deal with the impact of this type of admission, it seems appropriate to stress those types of technical analyses which provide information on the bounds to consequences rather than to stress those which purport to predict them accurately. Thus bounding and worst-case analyses using simple deterministic models continue to have important roles to play. Also the use of both natural and human analogues can help people relate to, as well as understand, what the technical information is telling us about system performance. Such analogues must be presented candidly so that any negative aspects are admitted and explained in a way which demonstrates circumstances under which each process is active and how it may impact on the potential dose received. Finally it is necessary to keep matters as simple as possible so that there is some hope of communicating the essential part of our understanding to non-technical groups. We must also be aware that increased complexity and sophistication are not necessarily associated with greater understanding. They are however, most certainly associated with greater difficulty in gaining public understanding and ultimately in gaining the confidence of the public.

In summary, it is evident that radioactive waste management decisions made using narrowly based techniques such as optimization of radiation protection do not correspond to real-life decisions made in many countries. It is suggested that the origin of these differences lies in fundamental differences of approach between technical and non-technical communities. The hope for the future therefore lies in establishing an effective dialogue between these communities rather than in refining our technical tools.

6. Conclusions

1. Politically-based considerations and processes including public perception and confidence appear to be the basis for real decisions affecting waste management activities such as siting, construction, operation and monitoring.

2. Optimization of radiation protection is not a useful general tool for waste disposal decision making.

3. Optimization of radiation protection is essentially a technical tool which can, under appropriate circumstances, provide a clear preference among major management options. The level of discrimination will be case-specific but, in general, only fairly coarse differences can be discriminated.

4. The preferences determined by optimization of protection tend not to be related to the final choices made for disposal of radioactive wastes.

5. Tools such as multi-attribute analysis are very useful as they provide a convenient means to rationalize the real decisions and give them some air of technical respectability. They do not, however, provide the primary basis for the decisions.

6. Technical experts must develop an awareness of the non-technical approach to decision making and attempt to adjust their method of analyses and their presentation of information to encourage dialogue rather than confrontation.

7. Simple expressions of technical information will be needed and the use of analogues should prove helpful.

7. References

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TABLE 1. RISK FROM WASTE TYPES

Waste	Specific Activitity	Scenario	Potential Dose		Probability
			Individual	Collective	
Mine Tailings	Low	Intrusion	High	High	High
Low Level	Low-Medium	Intrusion	Low-Medium	Low	Medium
High Level/ Spent Fuel	Very High	Well/Surface Water Ingestion	Zero-Low	Very Low	Low

TABLE 2. WASTE CHARACTERISTICS AND PERCEPTION

Waste	Waste Volume	Public Perception	Money Expended
Mine Tailings	Very Large	-Sand -Remote	Low
Low Level Waste	Medium	-Controllable -Use concrete -NIMBY	Medium
High Level Waste	Low	-Lethal -Eternal -Linked to bombs	High

TABLE 3. ROLE OF OPTIMIZATION IN REGULATORY PROCESSES FOR LONG LIVED RADIOACTIVE WASTES

	Is Formal Optimization Used?	Time Frame
Canada	No*	10^4 - all wastes
FRG	No	
Switzerland	No	
Sweden	Yes	
UK	No	
USA	No	10^4 - HL waste

*Possibility of a secondary role

TABLE 4. TIME SCALE PERSPECTIVES

Type of Scale	Time Frame (Years)	Perception	Importance to Decisions
Political	1 - 5	-Next election	Very High
Advocacy	3 - 10	-Public attention span	Medium - High
Social	25 - 70	-Life time -One - two generations	Medium
Biological	10^2 - 10^4	-Human history	Low
Geological	10^3 - 10^9	-Erosion -Ice age -Tectonic movement -Life of earth	Very Low